

Device and method for calibration of a microphone

The present invention relates to microphone output signal levels and more specifically to the calibration thereof to a desired level. When output levels of different microphones are compared, it is assumed that the acoustical excitations thereof are identical. Manufacturers supply microphones having output levels varying around a specified mean value. For the often used back-electret microphones, such tolerances are ± 4 dB. Consequently, the output levels of such microphones may show a difference of up to 8 dB. Microphones with tolerances of ± 2 dB are sometimes available. These, however, are more expensive.

A usual approach for gain calibration of a microphone is carried out in an anechoic chamber, i.e. a chamber without reflections or reverberation. A loudspeaker is placed in front of the microphone (at an angle of 0°) inside the anechoic chamber. The loudspeaker plays a noise sequence at a known power level and the power of the microphone response is measured. Subsequently, an adjustable gain is set.

Further an audio processing arrangement is disclosed in patent application WO 99/27522. According to this prior art reference, filtered sum and weighted sum beamforming are developed for maximizing power at the output. Filtered sum beamforming (FSB) makes the direct contributions maximally coherent upon adding thereof.

With multimicrophone algorithms such as beamforming, it is very important to sort the microphones during production to obtain sets with level differences within the required tolerances.

Moreover, with some multi-microphones systems, the consumer may buy additional microphones later in time, which will also have to be calibrated before installation.

The present invention provides a device for calibration of a microphone, comprising:

- a loudspeaker for converting a loudspeaker input signal into sound;
- a microphone for converting received sound into a microphone output signal,

and

Further advantages, features, and details of the present invention will become clear when reading the following description with reference to the annexed drawings, in which:

Fig. 1 is a perspective and partly diagrammatic view of a preferred embodiment of present invention in an audio conferencing system;

Fig. 2 is a diagram of a prior art setting for calibration of a microphone in an anechoic chamber;

Fig. 3 are graphs of a typical a.i.r. at 0° of a microphone and a corresponding energy decay curve (e.d.c.) as a function of time;

Fig. 4 are graphs of a typical a.i.r. at 180° on the same microphone as in Fig. 3 and the corresponding decay curve (e.d.c.) as a function of time;

Fig. 5 is a diagram of adaptive microphone calibration as included in the embodiment of Fig. 1;

Fig. 6 is a diagram of adaptive microphone calibration relative to a reference microphone which can also be used in the embodiment of Fig. 1;

Fig. 7 is a diagram of relative calibration relative to reference microphone which can also be used in the embodiment of Fig. 1; and

Fig. 8 is a diagram of a band pass filter and subsequent squaring and summation operation for use in the diagrams of Figs. 5-7.

Fig. 1 shows an audio conferencing system. It comprises a main console 1 and one or two satellite microphones 2 for a larger pick-up range of speech, which each contain a microphone, and is connected to a floor unit 23, which is connected to a power source 24 and a telephone network 25 of some kind, e.g. a PSTN (RJ11) or an ISDN (RJ45). The main console comprises, a loudspeaker for producing (voice) sounds, and three microphones for picking up (voice) sound. Furthermore, telephone means are comprised for making contact to other telephones through a telephone network. The microphones preferably inter-operate as seamlessly as possible. For this purpose, the invention provides means in order to allow for the abandonment of pre-installation calibration of the microphones in the satellite-microphones or even microphones in the main console.

Another example of use of a device according to present invention (not shown) relates to voice based commanding of a television set e.g. for switching channels or controlling the volume, by using microphone input. This can also be embodied in a form with one or several microphones. In order for a system to use the microphone output signal, calibration can be necessary.

For clarification some acoustical concepts are explained that are relevant for understanding the detailed description of the drawings. In Fig. 2, a loudspeaker 3 and a microphone 4 aiming towards that loudspeaker (thus at 0°) inside a room are shown.

An acoustic impulse response (a.i.r.) can be estimated from the loudspeaker excitation signal and the microphone response by correlation techniques. An a.i.r. is the response on an impulsive acoustic excitation. An example of such an estimated a.i.r. is depicted in Fig. 3. During the first few milliseconds the response is zero due to the delay from the limited sound speed in air. Next, a large peak can be observed, which is due to the response to the direct acoustic propagation of the sound from the speaker towards the microphone, and is called the direct sound field contribution. This peak has a normalized value of 1.0. The tail relates to this value as depicted in this graph. The tail of the a.i.r. is due to reflections against room boundaries, and is called the diffuse sound field contribution. These reflections have a random character and increase statistically in density and decrease exponentially in amplitude in time. The combined effects of the reflections are called reverberation.

An important function of the a.i.r. is the energy decay. In discrete time, with n the sample index, the energy decay at index n amounts to the energy left in the tail of the a.i.r.. In Fig. 3 the so-called energy decay curve (e.d.c.) corresponding to a.i.r. is also logarithmically plotted. On the Y-axis the quantity is measured in dB. The e.d.c. shows an abrupt change due to the direct component. The difference in energy decay just before and just after this jump is called the clarity index. A larger clarity index implies a larger direct/diffuse ratio and thus less reverberation. The envelope of the diffuse tail of the a.i.r. has an exponential decay which leads to the constant slope of the logarithm of the tail of the e.d.c. The reverberation time $T60$ is the time interval in which the reverberation level drops down by 60 dB. It is found for this case that $T60 = 0.36$ s.

Microphones can have unidirectional beam patterns. Unidirectional microphones only pick up acoustic signals from a certain range of angles around 0° ; they more or less block acoustic signals arriving at 180° . This means that the direct field contribution of an a.i.r. measured at 180° will be almost zero.

In Fig. 4 the a.i.r. and the e.d.c. of the same (unidirectional) microphone as of Fig. 3, but now at 180°, are plotted. There also is a value normalized to one, yet only the tail is shown as this represents the diffuse response. By comparing fig. 3 and Fig. 4 it appears that at 180° the direct contribution has vanished while the diffuse contribution has the same exponential envelope in both Figs..

In the following, it is assumed that the energy in the diffuse tail of the a.i.r. does not depend on the microphone or loudspeaker orientation and location in the room. In practice some variation are found depending on orientation and location, but these variations are small when the acoustic absorption pattern in the room is more or less homogenous and the reverberation in time is not too small ($T60 > 100$ ms). It is worth mentioning that a typical room has a reverberation larger than 300ms. A general rule is that the bigger a room is the longer the reverberation time is.

The present invention uses as input not only the microphone response but also the excitation signal of the loudspeaker (Fig. 2). First, the a.i.r. is estimated from the loudspeaker to the microphone using a well-known correlation method in the estimating means. When acoustic cancellation is performed, this adaptive filter is already available. The diffuse part of the a.i.r. is selected in the direct part removal means. At low frequencies the loudspeaker output and/or the microphone sensitivity is low, which leads to unreliable a.i.r. coefficients. Therefore a high-pass filter is applied to the diffuse part of the a.i.r. at the highest frequencies, near the Nyquist frequency, the signal levels will also be low due to anti-aliasing filters. Thus, to deal with unreliable a.i.r. coefficients at high frequencies a low pass filter is applied.

In Fig. 5, these high and low pass filters are combined to a band pass filter. The filtered coefficients are squared and summed in the squaring and summation means, which leads to actual power level 14 representing the current power of the diffuse microphone response. This power level is related to a desired power level 20 and the gain factor is determined as the square root of the quotient of these power levels.

In the preferred embodiment this calibration method can be applied each time the adaptive filter comes up with a new estimation of the a.i.r. For increased robustness of an acoustic echo canceller a programmable filter is sometimes used (as described in US 4,903,247). The adaptive filter runs in the background and the programmable filter, which takes its coefficients conditionally from the adaptive filter, is used for the actual echo removal. In this case it is best to take the coefficients of the programmable filter and apply the calibration procedure after each coefficient transfer.

Fig. 7 shows how the building blocks of Fig. 5 and 6 can be combined for referential calibration for use in e.g. an audio conferencing system as in Fig. 1.

Fig. 8 shows graphically how the averaging algorithm would work in calculating the power P of a diffuse sound field response of a microphone. The scheme
5 consists of a band pass filter followed by summation of the squared output values. At a sampling rate of 8 kHz good filter parameters leading to low-pass and high-pass cutoff frequencies (-3 dB) of about 200 Hz and 3.6 kHz, respectively, are $b=0.800$, $a_1=0.128$, and $a_2=0.621$.

The present invention is not limited to the above preferred embodiments; the
10 rights applied for are defined in the annexed claims.

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